

DEVELOPING A SCIENTIFIC BASIS FOR SOURCE WATER PROTECTION POLICIES IN THE SALT LAKE CITY WATERSHED CANYONS

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Biographical Sketch of Authors

The presenting author, Lindsay Griffith, is an environmental engineer with Brown and Caldwell in Denver, Colorado. Lindsay received her bachelor's degree from Texas A&M University in Agricultural Engineering in 1998, and her master's degree in Agricultural and Bioresource Engineering from Colorado State University in 2000. Her specific interests include water resources engineering, water quality monitoring and data analysis. Michelle Wind is a project engineer with Brown and Caldwell who worked with Lindsay in developing the water quality information system for Salt Lake City discussed herein. Florence Perez-Reynolds is the Water Quality and Treatment Administrator for the Department of Utilities of Salt Lake City who envisioned the creation of a monitoring system to aid the city in understanding the entire watershed which supplies the city's drinking water.

Abstract

The Salt Lake City Watershed Canyons water supply is a unique system given its proximity to a growing population, recreation attraction and the direct stream flow that brings water from high in the watershed to the water treatment system in just a few hours. The City, along with Brown and Caldwell, has developed water quality monitoring and response plans as part of a water quality information system to provide a basis for continuing watershed protection strategies. Development of the monitoring and response programs included input from a Blue Ribbon Panel of national and regional experts and is designed to establish baseline water quality and track water quality issues and changes that may result from growth and changes in land use activities.

This information-oriented approach includes all aspects of data collection and information utilization from sample collection and analytical procedures, through the statistics of data analysis and the incorporation of information into decision-making for watershed and water quality protection. The information system created through this monitoring plan is integrally linked to the City's water quality management goals.

In order to use the water quality information system to support management decisions, Salt Lake City staff expressed the strong desire to obtain water quality information that statistically and scientifically characterizes the water quality in the Watershed Canyons. For the Watershed Canyons monitoring program to be scientifically defensible, the information needs of the City were defined in a way which allowed analysis results to fulfill those needs. In this way, interpretation of water quality data analyses will provide the exact information that Salt Lake City needs to manage the Watershed Canyons and protect its water supply.

Introduction

The Watershed Canyons are comprised of seven unique canyons along the Wasatch Front Mountain Range. The Watershed Canyons are the primary source of water supply for Salt Lake City, mandating privileged protection. The snowmelt runoff from these mountain watershed canyons can reach Salt Lake City's raw water intakes and water treatment facilities within only a few hours. The hydrologic characteristics of the Watershed Canyons, such as fast-flowing, steep gradient creeks and rivers and the absence of reservoirs preceding treatment, afford minimal buffering to protect against water quality impacts (see Figure 1).

As growth and recreational pressures in the Watershed Canyons continue to increase, so will water quality impacts. The City recognizes that use of the Watershed Canyons will continue to grow with the population along the Wasatch Front. Property development opportunities for commercial, recreation, and residential uses are constantly sought, adding to the incremental water quality pressures on the Watershed Canyons. In light of these issues, the city has contracted with Brown and Caldwell to re-work their Monitoring Plan to build upon the existing monitoring system, establish baseline water quality in the Canyons, and help track how changes in watershed use affects water quality. As host to the 2002 Olympics, Salt Lake City has a unique opportunity with this Monitoring Plan to evaluate a temporary, but substantial increase in population and use of the Watershed Canyons. The monitoring plan will assist in evaluating this unique situation to help plan for long-term growth.

An initial step in the project was to integrate input from a panel of experts. Salt Lake City wanted to get insight from national experts, as well as experts from local universities, which could provide long-term continuity for future studies and project developments. Brown and Caldwell organized a panel of nine local and national water quality experts in the fields of microbiology, watershed management, water quality monitoring and water quality law to provide input into the plan development. The panel will reconvene later in 2002 to evaluate the data and analyses for the prior year. Key components of the effort includes review of existing monitoring activities and making recommendations for modifications to fill data gaps or reduce monitoring, where possible.

Source Water Protection Policies

Salt Lake City has the benefit of cooperative jurisdiction in its watershed canyons and has implemented extensive water quality protection policies. However, continuing development and recreational pressures in the canyons pose a threat to water quality. With the demand for increased use, developers, residents, recreationists, and others with canyon-related interests are demanding the scientific basis for the protection policies. Salt Lake City has identified a need for sound science and data to support common sense approaches for protecting its source water.

The City is authorized by Utah State law to enact ordinances necessary to protect the Watershed Canyons by preventing pollution or contamination to its water supply (Utah Code Ann., 10-8-15). Under Title 17 of the Salt Lake City code, the City has adopted several ordinances for water supply protection, including:

- Regulation of subdivision development,
- Regulation of animals within the watershed (including dog permits and prohibition of livestock near streams),
- Regulation of sanitary facilities (i.e. septic systems, waste disposal sites, prohibition locations of toilet vaults),
- Regulation of water pollution (including campfire restrictions), and
- Enforcement of watershed ordinances.



Figure 1. Watershed Canyons Hydrologic Setting

The City also uses other measures to balance development and protection of the canyons. This is accomplished through planning, zoning and coordination of an interagency site development plan approval process. Recent zoning ordinances have been adopted to protect sensitive lands, and include provisions for increasing stream setbacks and tighter restrictions on disturbance of the landscape during construction. In addition, the City receives help from the Salt Lake City Health Department and the USDA Forest Service in managing development and land use activities that pose a potential threat to water quality.

The size and diversity of the watershed canyons increases the complexity of issues among user groups, management agencies, and environmental groups. These issues include, but are not limited to such topics as:

- Microbiological contaminants from recreation
- Development impacts
- Wastewater collection and management
- Erosion
- Chemical use in the canyons (e.g., lawn care)
- Wildlife impacts
- Snowmaking additives
- Appropriate level of automobile traffic
- Fire management, i.e., attack and suppress vs. controlled burns

Watershed Monitoring Program

The purpose of the water quality Monitoring Plan is to facilitate sound water quality management decisions and ensure long-term protection of the City's source water as part of a larger water quality information system. The Monitoring Plan is designed to establish baseline water quality and track water quality issues and changes that may result from growth and changes in land use activities. The Monitoring Plan consists of sampling, laboratory analysis, data analysis, interpretation, reporting and information utilization.

Water quality information is crucial to municipal drinking water providers. The Salt Lake City Department of Public Utilities is the primary agency that implements the plan and uses the plan and the information it produces to ensure protection of their drinking water source. The water quality information system created through the Monitoring Plan is integrally linked to the City's water quality management goals.

Water Quality Management Goals. The water quality management goals outlined by Salt Lake City were developed to ensure compliance with regulatory expectations, as well as to ensure protection of Salt Lake City's water supply while maintaining multiple uses in the Watershed Canyons. The four goals listed below serve as the driving factor between monitoring information and management decisions regarding the protection of water quality in the Watershed Canyons.

- I. ***Ensure antidegradation.*** All streams in the Watershed Canyons are classified as Category I - High Quality Waters, which means they must maintain their existing high quality under the State antidegradation policy. Salt Lake City wants to ensure this high quality is maintained, by defining a baseline water quality and annually evaluating water quality for degradation.
- II. ***Comply with standards.*** The State of Utah, through the Division of Environmental Quality (DEQ), has primacy over the implementation of the Clean Water Act and Safe Drinking Water Act. The streams and creeks in the Watershed Canyons are designated and protected under a variety of uses, including domestic water supply with prior treatment, secondary recreational contact, cold-water aquatic life species and agriculture uses. A variety of physical, chemical and biological water quality standards have been adopted by the Utah Water Quality Control Board to protect these uses. In addition, Salt Lake City must comply with drinking water standards.
- III. ***Identify pollution problem areas and sources.*** Salt Lake City's water quality monitoring plan will ideally quantify changes in water quality over time. Some changes, however, may indicate water

quality degradation. In this event, special water quality studies will supplement the baseline program and help the City understand where the problem is occurring and why.

IV. *Improve water quality where possible.* Salt Lake City will continue to strive for superior water quality and lowering existing levels of constituent concentrations and loads in the watershed. When results of the monitoring plan and special studies indicate a pollution problem and its source, the City can make decisions regarding protection measures, such as implementing best management practices (BMPs), water quality management strategies, and developing water quality ordinances.

Management Structure . Water quality information is crucial to municipal drinking water providers. The Salt Lake City Department of Public Utilities will be the primary agency that implements the plan in its day to day activities, uses this plan and the information it produces, amends the plan when appropriate changes are required, and disseminates the water quality data and information to decision-makers, regulators, and the public. The Utility's management team rely on this water quality information on a daily basis to ensure drinking water source protection.

Salt Lake City has conducted water quality monitoring and collected data in the Watershed Canyons for over 20 years. Over this period of time, the water quality monitoring program has been complimented with various water quality laws and watershed protection policies geared to preserve water quality in the Watershed Canyons. Historically, Salt Lake City's water quality monitoring program tended to focus on the actual means for collecting data, with the acquisition of data being the endpoint. Traditionally, this monitoring program has collected data on total and fecal coliforms, metals, and nutrients, with limited focus on the information purpose for monitoring. In order to ensure long-term source water protection and better support its management decisions and communication with the public about water quality issues in the canyons, Salt Lake City decided to update its water quality monitoring program. In April 2001, the Watershed Canyons water quality Monitoring Plan was implemented.

Monitoring Information Needs. Salt Lake City requires water quality information that scientifically characterizes the water quality in the Watershed Canyons. This water quality information will be critical to thoughtful decision-making.

For the Watershed Canyons monitoring program to be scientifically defensible, the information needs were defined in a way that allowed analysis results to fulfill those needs. In this way, interpretation of water quality data analyses provides the exact information that Salt Lake City needs in order to manage the Watershed Canyons and protect its water supply. Each of these information needs is defined under each water quality management goal, as listed below.

Goal I: Ensure antidegradation.

- ❑ ***Information Need #1.*** Establish baseline quality in the canyons.
- ❑ ***Information Need #2.*** Determine if degradation occurs.

Goal II: Comply with standards.

- ❑ ***Information Need #1.*** Define the instream standards with which each stream must comply, and define how a violation occurs
- ❑ ***Information Need #2.*** Determine the extremes in water quality, i.e. the range of values, the number of samples that exceed the standards, and the percent of violation.

Goal III. Identify pollutant problem areas and sources.

- ❑ **Information Need #1.** Identify existing land use activities and potential contaminant sources in each canyon via a watershed inventory.
- ❑ **Information Need #2.** Identify suspected areas and pollutant sources in each canyon.
- ❑ **Information Need #3.** Determine if statistically significant degrading trend exists at suspected site over the period of record.
- ❑ **Information Need #4.** Determine if samples from suspected site is “worse” than upstream site by detecting a statistically significant difference in annual sample medians for constituents of concern.
- ❑ **Information Need #5.** Identify unknown pollutant problems through continuous monitoring. Use this monitoring data to evaluate peaks in pollutant concentrations, and identify suspected sources.
- ❑ **Information Need #6.** Through special study monitoring, identify if correlation exists between turbidity or run-off events and pathogen concentrations where appropriate data are available (WTP inflow data).
- ❑ **Information Need #7.** Through special study monitoring, determine if high use of the canyon results in significantly “worse” water quality than baseline conditions.

Goal IV. Improve water quality where possible.

- ❑ **Information Need #1.** Identify pollution problem areas.
- ❑ **Information Need #2.** Identify appropriate mitigation measures for sources and constituents of concern.
- ❑ **Information Need #3.** Determine if water quality improved after implementation of mitigation through special study monitoring, by detecting a statistically significant difference (decrease) in annual median concentration after the mitigation implementation.

Data Analysis Protocol

The Data Analysis Protocol (DAP) for the Watershed Canyons water quality monitoring program is an integral part of the larger Watershed Canyons water quality information system. This system connects the monitoring network design to the management goals and water quality monitoring information needs in order to aid in the decision-making process. The DAP is the analysis phase, in which water quality data is interpreted into information for management.

This interpretation is typically accomplished through graphical and statistical data analyses means, which allow numerical data to be summarized into conceptual information which is reported to management and used in the decision process. Data analysis can be very labor-intensive, but it is imperative to interpret the data into information that management can utilize. It will be important to perform comprehensive data analysis on a regularly scheduled annual basis. This will include production of an annual Watershed Canyons monitoring program report to present the results of the analyses.

Selection of Analysis Methods. In order to completely integrate monitoring results with management goals, the selection of analysis methods is dictated by three major elements:

- Monitoring information needs,
- Characteristics of the proposed data analysis methods, and
- Data record attributes.

The DAP identifies and describes analysis methods which will be used to interpret data for the information required by Salt Lake City management. The data analysis methods utilized fall under the two broad categories of graphical methods and statistical hypothesis testing methods. Graphical methods are easily understood; various graphical means are used to represent the data in order to aid in its interpretation. Hypothesis methods are more mathematically rigorous methods that use probability characteristics of the data as evidence to reject the null hypothesis. These methods, though often contested for their biases and loose interpretation, are the most common form of validating hypotheses about the data.

The DAP includes provisions for amendments as information and data characteristics change. As the monitoring program progresses, periodic review is necessary to determine if the analysis methods are appropriate for the current data characteristics and the City's management goals.

Monitoring Network Design

The monitoring network design specifies the components that will provide the information needs required to support the water quality management goals. These components include sampling locations, constituents, and frequency. The monitoring network design builds on existing monitoring programs and outlines the items that need to be completed to support the water quality management goals and satisfy the information needs previously outlined.

The monitoring network design maintains consistency with constituents and sampling sites that have been historically monitored in the Salt Lake City Watershed Canyons. In addition, monitored constituents and sites were modified to ensure the water quality management goals would be met and to begin to develop baseline conditions for those constituents not currently monitored.

Detailed information was developed for sampling sites, constituents groups, and sampling frequency. Operating procedures, such as sample collection and handling procedures, analytical methods and sample preparation, and sampling equipment information such as maintenance and calibration procedures were provided. To a large degree, the components of the existing Salt Lake City monitoring programs and standard operating procedures were incorporated, and as needed, modifications were made to incorporate the water quality management goals.

Sampling Site Locations. Selection of representative sites for surface water sampling was based on many factors, but was primarily developed around the water quality management goals. Additionally, secondary factors considered included:

- Known or suspected water quality impact sources
- Tributaries, river or stream characteristics
- Human or natural impact areas
- Travel time to the water treatment plant (early warning system to address short travel times)
- Historical sampling sites for data continuity
- Accessibility

Monitoring Constituents and Sampling Frequency. It is important to maintain consistency with constituents historically monitored to ensure long-term baseline characterization. It is also important to modify monitored constituents to ensure management goals will be met and to begin to develop baseline conditions for those constituents not currently monitored. The frequency of monitoring for each constituent varies based on the information needs, quantity of historical data and the data requirements for statistical methods recommended for data analysis under the Plan.

Special Water Quality Studies. In addition to baseline monitoring, special studies address water quality under conditions that may not be captured through baseline monitoring. Special water quality studies and targeted

monitoring can identify short term or intermittent trends in water quality, which may impact development of recommended water quality management actions.

Targeted Monitoring. Targeted monitoring attempts to identify peak concentrations of constituents through additional monitoring during high public use periods such as weekends and holidays. Runoff from storm events and high-flow snowmelt periods were also recommended for monitoring. In addition, forest fires or other significant events in the watershed, could be monitored, if possible.

Provided below are recommended targeted monitoring events, which extend beyond characterizing baseline conditions and will assist in identifying pollutant problem areas and sources. A period of two years (2001 through 2002) was initially proposed for targeted monitoring to determine if water quality is affected by activities such as high public use periods and high runoff events, including storm generated high flow events and peak snow melt periods. After evaluation of the 2001 through 2002 targeted monitoring data, the need for additional targeted monitoring, or modifications, can be evaluated.

High Public Use Monitoring.

- Memorial Day Weekend
- Pioneer Day Weekend
- July 4th Weekend
- Labor Day Weekend

Snow Melt Runoff Sampling. Timing of spring snow melt in the canyons varies based on elevation but should be characterized from the initiation of snow melt through the highest snow melt period. For a two-year period, 2001 through 2002, sampling will be completed during the snow melt runoff period at a greater frequency than completed under the monthly baseline monitoring. This targeted monitoring is driven by the 2002 Winter Olympics, to be held at various locations in the Watershed Canyons. By collecting samples at increased frequency in the spring of 2001 (baseline) and the spring of 2002 (impacted by Olympics), the City can perform an analysis of differences between normal use and high density use in the winter. It is expected that the snowmelt period will be during the months of May, June and July.

Storm Runoff Sampling. For a two-year period, 2001 through 2002, monitoring will be completed during selected storm events. If possible, monitoring is recommended for a minimum of three storm events (rainfall events) per year during the late spring (after snowmelt) through the fall season. Precipitation should be sufficient enough to create runoff that increases stream flow. To fully characterize the rise and fall of stream flows, automatic samples were recommended at specific sampling sites.

Special Studies for Pathogens. To aid the City in interpretation of both baseline data and data collected through the above targeted monitoring, special studies are recommended to aid in the interpretation of pathogen data. Pathogens are often difficult to sample, and so must be collected at limited sites. If pathogen levels can be shown to be strongly correlated with either flow or turbidity, then these field parameters can be used to predict pathogen levels in areas where pathogen data does not exist. The City has two choices for implementation of this special study:

1. Ensure that turbidity and flow data are collected concurrently with pathogen data.
2. Implement a special study where pathogens, flow and turbidity are sampled intensively for a short period of time, in order to produce enough data for a correlation analysis.

The first option has the advantage of not requiring any more monitoring events, but the disadvantage that a long period of time (several months of weekly data) will be needed to provide enough data for analysis. The second option will provide a large data set in a short amount of time (i.e. daily samples taken for a month), but the data won't represent fluctuations and variability through the seasons.

Implementation of the Water Quality Monitoring Plan

The City implemented this water quality monitoring plan in April 2001 to obtain three seasons of data, including spring runoff, prior to the 2002 Winter Olympics. The City has begun preliminary analysis of data it has received to date, primarily data through the fall of 2001. The following preliminary data show how the monitoring plan is initially assisting the City in evaluating what is happening in the watersheds, both spatially and temporally.

Figure 2 shows that average total coliforms are at relatively low levels and that concentrations are consistently higher on the weekends versus the weekdays. The City has used total coliform data for twenty years as a water quality indicator. Figure 3 shows that total coliforms appear to increase on weekends and storm events, but that *E. coli* does not necessarily follow the same pattern.

Preliminary pathogen data also shows how the monitoring plan can help the City identify issues such as increased pathogens in a specific canyon (Lambs Creek) (see Figure 4). This data can then be linked to uses in the canyon, such as older septic or wastewater vault systems. These data are presented to show how basic information can assist the City in getting an idea of potential issues in different watersheds or how other factors such as storm runoff and higher use periods can impact water quality differently in the watersheds.

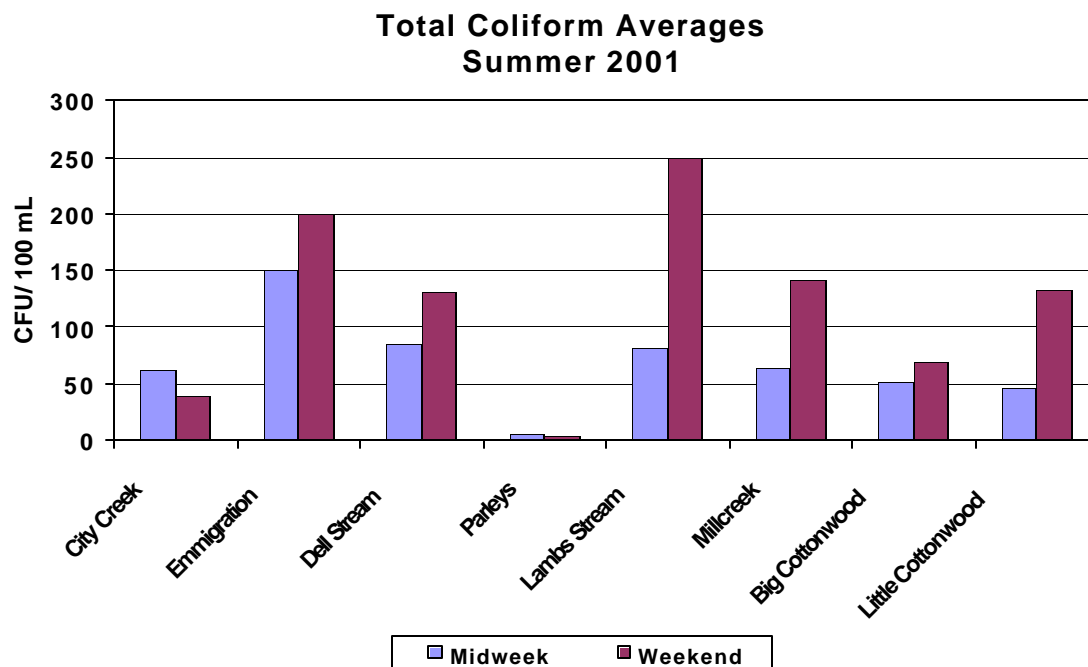
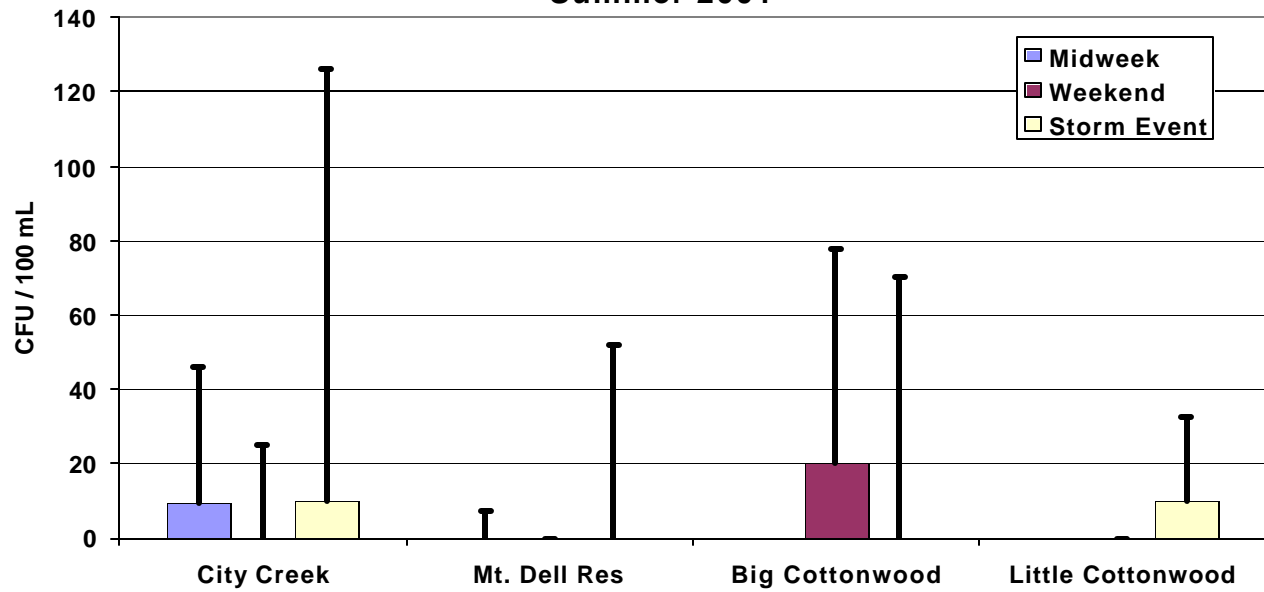


Figure 2. Weekday and Weekend Total Coliform Concentrations

E. coli
Median and 95th Percentile Values
Summer 2001



Total Coliform
Median and 95th Percentile Values

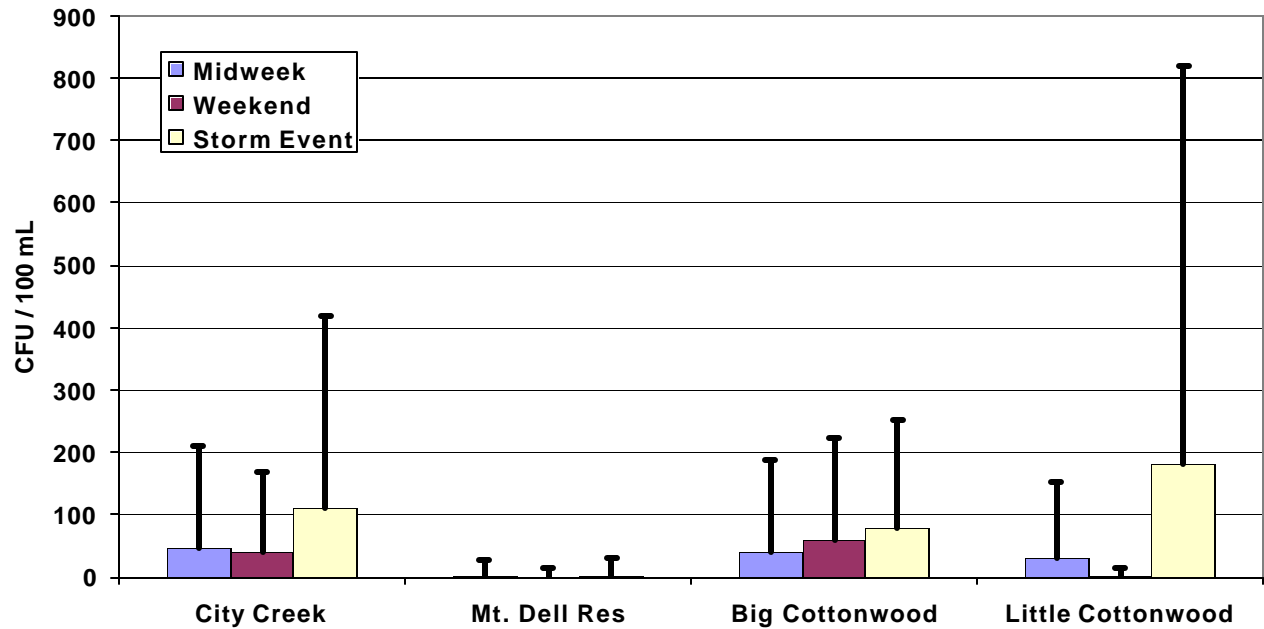


Figure 3. Total Coliforms and *E. coli* Concentrations for Weekdays, Weekends, and Storms

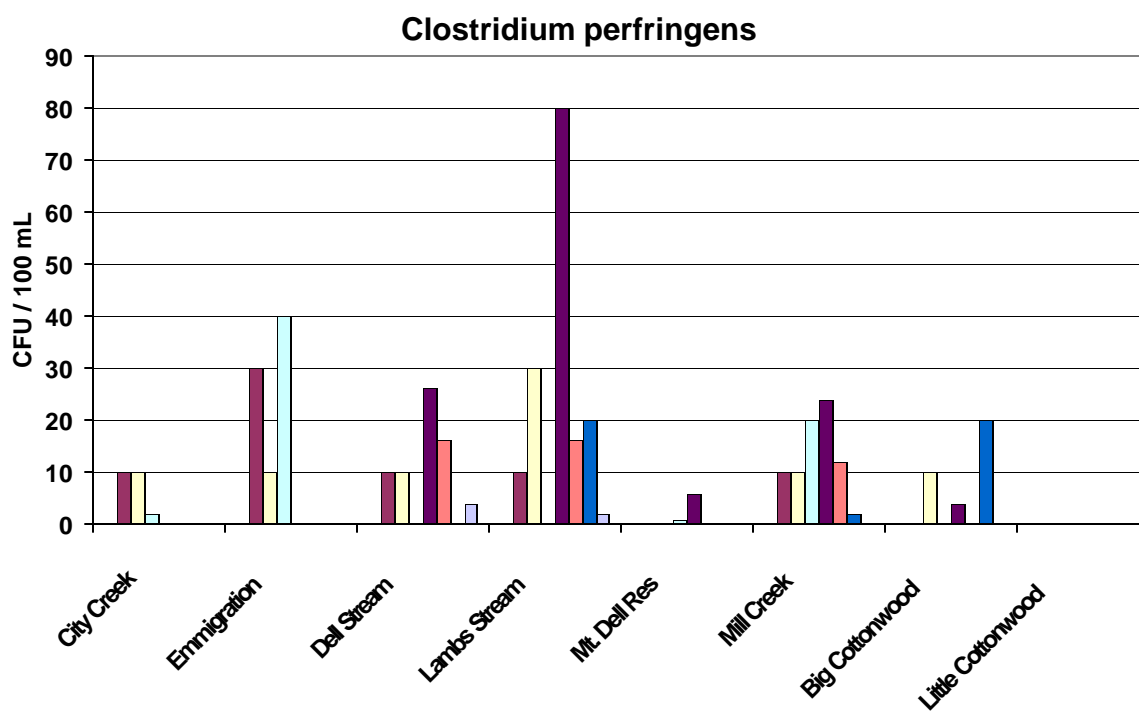
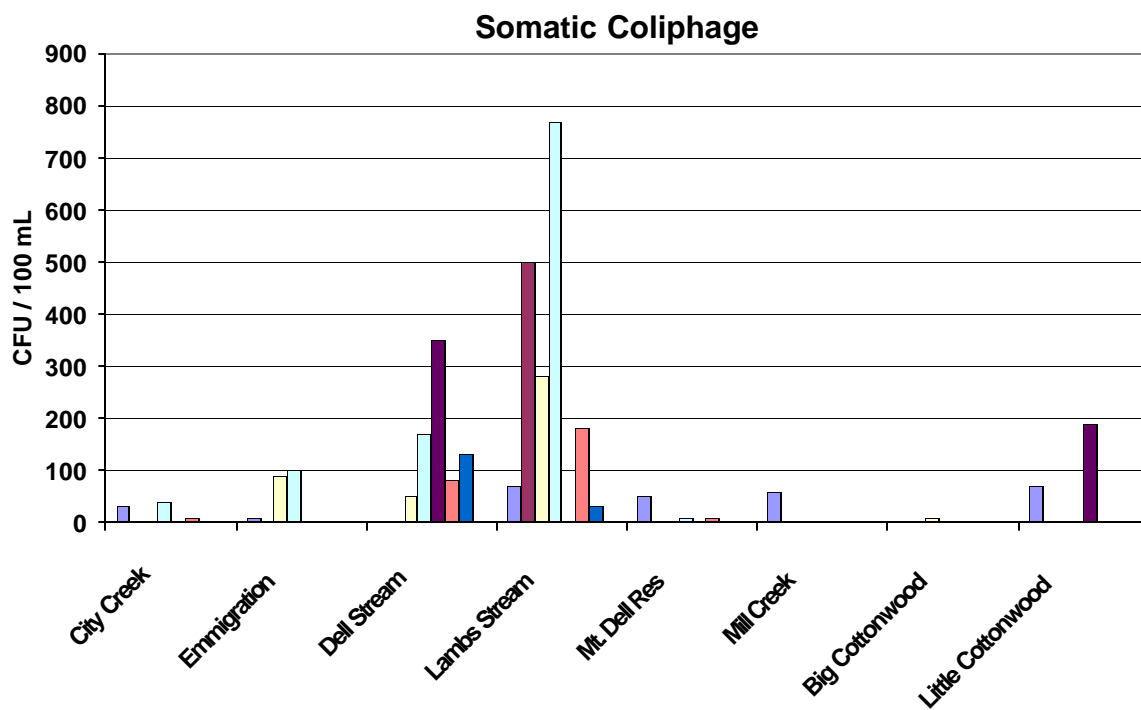


Figure 4. Microbiological Data in Salt Lake City Watershed Canyons

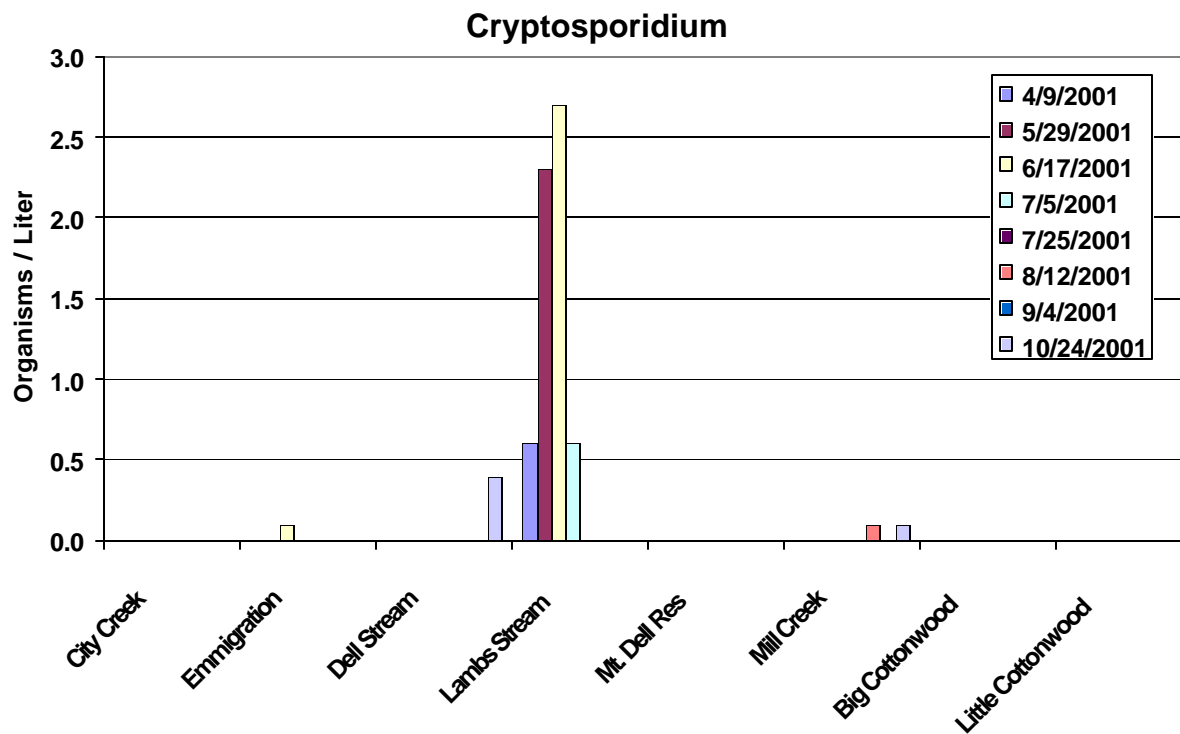


Figure 4 (continued). Microbiological Data in Salt Lake City Watershed Canyons

Recommendations

In addition to the Monitoring Plan, the Expert Panel also identified the following recommendations, which were intended to supplement the monitoring program and provide a guide for the City in gathering additional information in working toward the management goals.

1. **Perform a Comprehensive Watershed Inventory.** The purpose of the inventory is to locate, quantify and evaluate existing and potential sources of contamination. The City already has a thorough understanding of existing and potential land use activities and the inventory process is intended to document and supplement current knowledge. A watershed inventory can refine monitoring needs by targeting locations and constituents and monitoring can assist in tracking and quantifying contaminant sources and impacts. The inventory would include coordinating with other land use management entities to obtain information and data (e.g., visitor days, vehicle counts, septic system locations, locations of accidental spills, areas with high erosion potential, permit information, etc.).
2. **Establish a Continuous Monitoring System.** The importance for a continuous monitoring system to provide an early warning system to the water treatment plants and provide more accurate information for identifying and tracking potential contaminant sources was identified. The short travel time and a lack of buffering characteristics prior to water treatment decreases the reaction time of water treatment plant operators to respond to incoming contaminants that might affect treatment. This type of system would provide plant operators with real-time data to assist in process control, as well as data that can supplement long-term data for watershed management to help define potential sources of contaminants.
3. **Perform a Risk Assessment.** A risk assessment provides a statistical analysis of data and would incorporate watershed inventory and water quality data to estimate risk related to the City's water supply. A risk

assessment can assign the probability of an event and related risk to watershed land use activities. A risk assessment can also be used to evaluate management options. Such a risk assessment would provide a basis for watershed protection activities and policies by quantifying and providing an objective foundation for prioritizing existing and potential contaminant sources. This assessment could be used to prioritize resource allocation for protection efforts based on the level of potential risk.

4. **Conduct Macroinvertebrate Monitoring.** Biological monitoring can supplement chemical monitoring by providing an indication of both acute and chronic water quality impacts. The City has performed limited and infrequent macroinvertebrate monitoring in the past. Annual macroinvertebrate monitoring was recommended. This monitoring is resource intensive (both labor and analytical) and it was recommended that the City consider a coordinated monitoring effort with state and federal agencies.
5. **Prepare for Response Monitoring and Special Studies.** The Monitoring Plan is designed to provide monitoring data and analyses to identify factors that can affect both short-term and long-term water quality. Once a potential water quality issue is identified, more intense, response monitoring will be needed to determine the source and location. As a result, the City will need to develop a process for response monitoring based on the constituent, upstream land use, and potential sources.
6. **Conduct Targeted Monitoring for Human Impacts.** The Expert Panel recommended the use of constituents that specifically originate from humans to evaluate water quality impacts solely from human waste. Indicator constituents include chemicals such as triclosan (a component in soap) and ibuprofen. This recommended targeted monitoring could be used as a tool to supplement the baseline monitoring when human waste impacts are suspected.

Conclusions

The City will perform comprehensive data analysis on a regularly scheduled basis. In this first year, this includes establishing its site-specific baseline water quality data and gaining an understanding of the dynamics and impacts in the watershed based on targeted monitoring. Of particular interest to the City is gaining an understanding of the impacts of the 2002 Winter Olympics and potential long-term impacts of increasing and changing uses in the Watershed Canyons.

References

- Brown and Caldwell. 2001. *Salt Lake City Watershed Canyons Water Quality Monitoring and Response Plans*.
- Salt Lake City Department of Public Utilities. 2002. Watershed Canyons water quality monitoring data and preliminary data analyses, April 2001 through November 2001.